Formation of memristor structures based on ZnO thin films by scratching probe nanolithography

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Development of the next generation computer memory is the promising direction of electronics. One of the promising types of memory is metal oxide memristor structures-based non-volatile resistive memory (RRAM), which has high-density integration, low-power consumption, and fast write/read operations. Zinc oxide (ZnO) is the one of the promising oxides, which widely used in electronic element developments, sensors and microsystem technology. Also ZnO demonstrates memristor effect and is compatible with semiconductor technology [1,2]. To fabricate ZnO based RRAM it is necessary to carry out prototyping and investigations of ZnO memristor structures. Thus, it becomes necessary to develop new nanolithography techniques, which allow fabricating the structure of elements of RRAM at lower expenses and within shorter periods than conventional methods of photo- and electron-beam lithography.

One of the promising methods for the formation of nanoscale structures is scratching probe nanolithography (SPN) of atomic force microscope (AFM) [3,4]. The SPN method involves the modification of thin polymer films by the formation of profiled nanosized structures using the tip of the AFM probe. Through the profiled nanosized structures various technological operations (deposition, etching) could be performed. The advantages of SPN include high resolution and the absence of physical templates. Various structures of the elements of nanoelectronics and microsystem engineering were formed using SPM.

The aim of this work is fabrication of ZnO thin film-based memristor structures using scratching probe nanolithography, and also investigation memristor effect on them.

ZnO thin film was grown using pulsed laser deposition technique. Al_2O_3/ZnO:In as a wafer was used. Deposition performed under the following conditions: wafer temperature: 400°C, target–wafer distance: 50 mm, O_2 pressure: 1 mTorr, pulse energy: 300 mJ.

The solution of photoresist/thinner (FP-383/RPF383F) at volume ratios of 1: 10 was transferred onto ZnO using the centrifugal method at the rotation speed of a Laurell WS-400B-6NPP centrifuge 5000 rpm. After the deposition of the film, the photoresist/thinner film was dried at the temperature of 90°C for 25 min. Thickness of the photoresist/thinner film was equal to 75.1±3.3 nm.

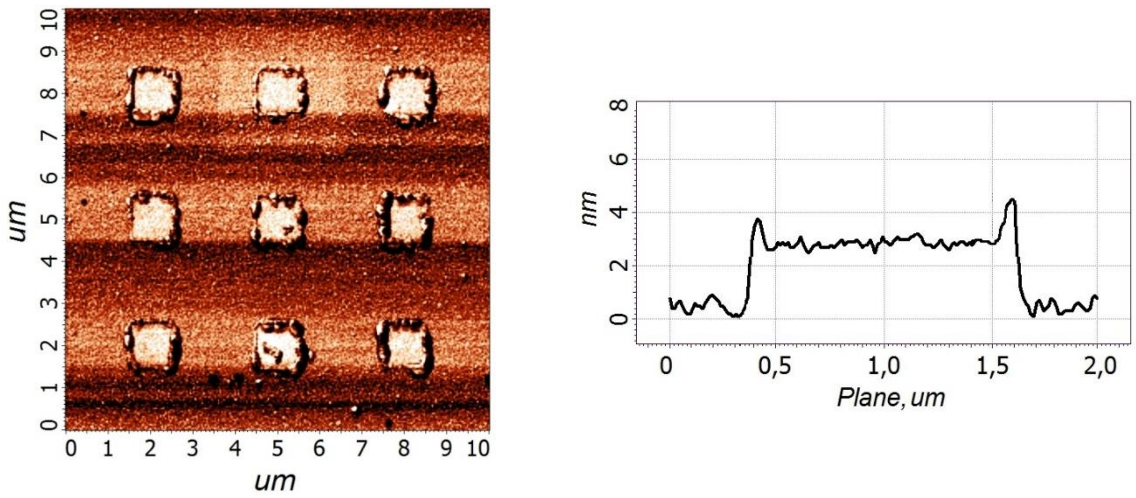
Scratching probe nanolithography (SPN) on the photoresist/thinner film was performed using a Solver P47 Pro scanning probe microscope (NT-MDT, Russia). Thus, array of the 9 squared nanostructure-grooves was formed. Then thin Ti film was deposited using BOC Edwards Auto 500 system. After that lift-off process was applied using dimethylformamide.

Electric measurements of the Al_2O_3/ZnO:In/ZnO/Ti structure was carried out using Solver P47 Pro oscilloscope. ZnO:In film was grounded during measurements. W_2C AFM probe was used as a top electrode. Current-voltage curves were obtained at –3 to +3 voltage sweep.

Figure 1 shows experimental investigation of ZnO and Ti films morphology. It is shown that ZnO film surface has a granular structure with 0.12±0.26 μm^2 grain size (Fig. 1a). Thickness of Ti structures was equaled 2.5±0.4 nm (Fig. 1b). The ZnO film thickness was investigated using AFM by scanning bottom electrode/ZnO film boundary, and was equaled 10.2±3.4 nm.

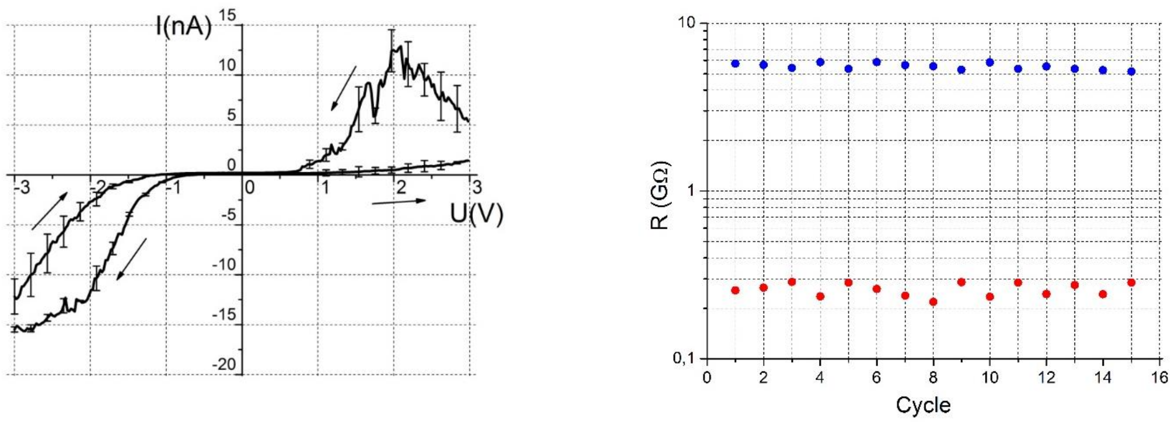
Figure 2 shows electric measurements of Al_2O_3/ZnO:In/ZnO/Ti/W_2C structure. Resistive switching from high resistance state (HRS) to low resistance state (LRS) was occurred at 2.1±0.3V, and from LRS to HRS at -1.5±0.3 V (Fig. 2a).

Endurance test shown that HRS was 5.5±0.4 GΩ, LRS was 2.3±0.3 GΩ (Fig. 2b). The HRS/LRS coefficient was equaled 21±3 at –3 to +3 voltage sweep. Read voltage was 1.5 V.



(a) (b)

Figure 1. 3×3 array of Ti structures: (a) AFM-image; (b) average profilogram of Ti structures.



(a) (b)

Figure 2. Electric measurements of Al_2O_3/ZnO:In/ZnO/Ti/W_2C structure:
(a) current-voltage characteristic at –3 to +3 voltage sweep; (b) endurance test.

The results can be useful for micro- and nanoelectronics elements manufacturing, as well as micro- and nanosystem engineering using probe nanotechnologies and for ZnO- based RRAM fabrication.

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